Cross Cascades Corridor Analysis Project

Technical Memorandum No. 1
ITS Speed Monitoring System Options for Application in Washington

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for the
Washington State Department of Transportation

Purpose and Background

An analysis of ITS speed monitoring system options has been conducted to identify the costs and benefits associated with different approaches to collecting data. ITS technology provides actual data regarding the speed of vehicles traveling between two points, offering a more comprehensive and detailed snapshot of traffic patterns at different locations. Currently, transportation planning in Washington State is based on estimates of travel time derived from data available from traffic volume counts and measured speeds at a single location.

The three technologies, described and evaluated in this report, were identified for further analysis after a preliminary examination and discussion of a larger sample, including:

- Automated Vehicle Identification (AVI);
- Video Imaging Technology;
- Global Positioning System (GPS) Floating Vehicle Technology;
- Cellular Phone Technology; and
- Loop Detectors.

Loop detectors, which can provide accurate data at a single point but not along a road segment, were eliminated from further consideration because of the high costs associated with implementing this technology outside urban areas. Cellular phone technology was also eliminated from further consideration because of high initial start-up costs as well as concerns regarding the privacy of drivers.

Privacy is not an issue with any of the technologies identified for further analysis, but because of potential concerns associated with video technology, it is only briefly addressed as part of the analysis.

A common problem shared by all of these technologies is the inability to determine the cause of traffic stoppage. If vehicles identified at one point fail to appear at the next, it is not possible to determine the reason without confirmation of a road closure or disruptive event from another data source. In urban areas with traffic management centers, this information is typically available from video cameras, though it may not be stored.

Method and Structure of Report

This analysis focuses on statewide connectors linking the state's metropolitan urban areas, rather than the urban areas themselves, because (a) some technologies already are in place in urban areas, and (b) the unique features of these areas means no one technology is appropriate for the variety of road conditions. Urban segments of interstates are part of the network addressed here. The road network, analyzed for the purposes of this report, is the State Highway System Plan, including:

Interstate Highways	U.S. Highways	State Highways
I-5	US 2	SR 3
I-90	US 12	SR 4
I-82	US 97	SR 8
I-205	US 101	SR 14
	US 195	SR 17
	US 395	SR 20
		SR 26
		SR 28
		SR 104
		SR 127
		SR 270

The following sections of the report, each of which examines the costs and benefits of one of the three technologies, are organized around a number of topics. After a brief description of the technology, the following topics are addressed:

Basic Costs. This section discusses the issues and costs associated with establishing a system at minimum levels of accuracy. It includes the fixed capital costs and annual operating costs for monitoring travel times on rural routes only. Coverage of urban areas is excluded here because (a) some technology is already in place in most urban areas, and (b) it would increase costs significantly to implement two of the three technologies at a level of meaningful accuracy in these areas.

Accuracy. This section discusses the issues and costs associated with achieving higher degrees of accuracy in the data generated by the different technologies. It also includes coverage of urban freeways, which would provide data comparable to that available for statewide connectors.

System Enhancements. This section discusses the issues and costs associated with providing real time data for the purposes of traffic management. It applies to AVI and video imaging technologies only and would entail automating data retrieval and transmission processes.

This information is summarized in the attached matrices (Tables 1 and 2), which allows for easy comparison of the costs and issues associated with the different technologies.

Information regarding each of the technologies comes from two sources: (a) experience in Washington State with Automobile Vehicle Identification (AVI) (Spokane) and Global Positioning System (GPS) (Seattle), and in Oregon with Video Imaging; and (b) the FHWA, "Travel Time Data Collection Handbook" (Report No. FHWA-PL-98-035, March 1998).

Automated Vehicle Identification (AVI)

General Description

AVI detectors, located along a route, pick up signals from transponders located in passing vehicles. By comparing the exact time each transponder passes each reader, the speed of the vehicle can be calculated. Because the transponder numbers used in data collection would not be associated with specific vehicles in the database, there would be no privacy issue. This technology is currently being used in the Spokane region.

Basic Costs

There are three cost components associated with the implementation of an AVI system:

- Capital cost of AVI detectors;
- Transponders to be located in vehicles;
- Cost of downloading data from detectors and detector maintenance; and
- Cost of central data processing.

A significant cost issue is the spacing of reader locations. Fifty-mile spacing is used as a baseline in this analysis, but would require a sufficient number of transponder-equipped vehicles to provide a reading of minimum accuracy. A potential problem with this approach is that a vehicle could stop for a short period of time (up to 10-15 minutes) and still travel to the next reader without being outside the normal distribution of travel speeds. In the absence of a sufficient sample of vehicles on that road segment, such incidents could significantly bias the speed data downward.

Since accurate readings in urban areas requires spacing of no more than five miles, implementation of AVI in urban areas was not included as part of the basic costs calculation.

Capital cost of AVI Detectors (readers). At 50-mile spacing along the rural routes included in the Washington State Highway System Plan, 141 sites would need to be equipped with AVI detectors, for a total cost of $2,416,000.

Transponder costs. The type of transponder used with AVI technology costs $40. To obtain sufficient numbers of vehicles for accurate readings in rural areas, at least 1percent of the vehicle fleet would need to be equipped with transponders. Accuracy at 50-mile spacing would require a greater number of vehicles on the road, which for the purposes of this analysis has been estimated at 22,000, for a total cost of $800,000. Because transponders have a four-year battery life, beginning in year five there would also be an annual replacement cost of $220,000.

Maintenance and data download costs. The costs associated with traveling to reader sites; manually downloading data, and performing any needed maintenance, were estimated at one hour per site per month. Assuming the services of a technician with a fully loaded rate of $30 per hour, the annual cost of downloading and maintaining 141 reader sites would be $50,760.

Central data processing costs. Computers, data storage, and software were estimated at $5,000 per region, for an annual statewide total of $30,000. The costs associated with technicians responsible for data processing and analysis were not estimated for the purposes of this analysis.

Accuracy

The accuracy of the technology depends on the spacing of reader sites and the number of vehicles equipped with transponders. By decreasing the spacing of AVI detectors to 10 miles, it would be possible to identify vehicles that stop for periods as brief as 5 minutes and remove them from the distribution, thus significantly improving the accuracy of the data. This would almost triple the number of reader sites and the costs associated with their installation and maintenance.

The implementation of AVI technology on the urban segments of the State Highway System Plan was included at this stage of the analysis to reflect the cost associated with providing comparable data for the entire road network. In urban areas, this technology is appropriate for freeways, but not local arterials, and therefore only the former was included in cost estimates. Within urban areas, 5-miles or less spacing of readers is the generally accepted standard for minimum accuracy.

Capital cost of AVI Detectors (readers). The number of reader sites on rural roadways would increase to 368 ($6,320,000), and an additional 39 sites on urban roadways ($1,120,000), for a total fixed capital cost of $7,440,000.

Maintenance and data download costs. These costs would increase with the number of additional reader sites installed. Annual costs on rural roadways of $132,480 and on urban roadways of $14,040 would result in a total annual cost of $146,520.

Transponder costs. There would be no additional costs associated with transponders. A closer spacing of readers would require fewer vehicles to produce accurate readings, and therefore the earlier estimate of 22,000 transponders could be allocated across the entire road network.

Central data processing costs. An increase in the number of reader sites should not impact the costs associated with central data processing.

Relative accuracy. At 10-mile spacing, the technology would be more accurate than the GPS floating vehicle technology because it would be constantly measuring travel times throughout the year. However, unless there were a large number of transponders in the vehicle fleet it would be significantly less accurate than video imaging technology, which picks up more than 65percent of the vehicles passing any given location.

System Enhancements

The downloading and transmission of AVI reader data could be automated and provide real time data for traffic management purposes. If sites were wired for data transmission, eliminating the need to manually download data from reader sites, maintenance was estimated at four hours per site per year. Electronic downloads of this data would be conducted over phone lines, which was estimated at $100 per month per road segments for a dedicated line. A road segment would typically have between two and eight reader sites. At 50-mile spacing on rural roadways, the costs associated with automation were estimated at $90,120 (basic cost level). At 10-mile spacing on rural roadways, this cost would increase to $117,360; and would cost an additional $15,480 to similarly equip readers on urban roadways. The total cost associated with automating the downloading and transmission of AVI reader data under the "accuracy" scenario is $132,840.

Video Imaging Technology

General Description

Video imaging technology uses infrared cameras to read the license plates on passing vehicles. By comparing the exact times that any given vehicle passes two locations, the travel time can be determined. This technology has proven accurate enough to correctly identify 65 percent to 75 percent of license plates in both daylight and darkness.

To protect the privacy of motorists, current software typically truncates and encrypts license plate numbers before putting them into a database, which prevents the identification of a specific vehicle and the associated speed data. Privacy is often raised as a concern, in part because similar technology is used in law enforcement. Notably, where this technology is in use for the purposes of monitoring travel times, privacy issues have not arisen.

This method of collecting speed data should not be confused with other uses of video technology. Traffic monitoring cameras used by traffic control centers – which often provide for viewing on the Internet -- are not capable of reading license plate numbers. Cameras used at intersections to replace loop detectors can react to a vehicle passing through the "trigger zone," but do not identify the vehicle. Finally, red light cameras and photo radar are used by law enforcement and are not designed or used for general monitoring purposes. Most importantly, the video imaging technology used to obtain travel time data, like a number of the other uses of video technology, do not compromise the privacy of motorists subject to monitoring.

Basic Costs

There are three cost components associated with the implementation of video imaging technology:

- Capital cost of video camera reader sites;
- Cost of downloading data from cameras and maintaining sites; and
- Cost of central data processing.

The location of cameras would be based on the same criteria as AVI locations. As is true for the AVI technology, the distance between detection cameras necessarily affects accuracy. Basic costs were estimated at 50-mile spacing of cameras in rural areas for a minimum level of accuracy.

Capital cost of cameras. At 50-mile spacing along the rural routes included in the State Highway System Plan, 141 sites would need to be equipped with video imaging cameras, for a total cost of $3,130,807.

Maintenance and data download costs. The volume of data to be downloaded from video imaging sites will be much larger than transponder reader sites. The nature of the data, however, is no different, consisting of an encrypted vehicle identifier and a time stamp. There is no need to store or transmit the video images themselves.

The costs associated with traveling out to reader sites, manually downloading data, and doing any needed maintenance, are comparable to those associated with the AVI technology, and were estimated at one hour per site per month. Assuming the services of a technician with a fully loaded rate of $30 per hour, the annual cost of downloading and maintaining 141 reader sites would be $50,760.

Central data processing costs. Data processing costs were estimated at $40,000 for software, plus $10,000/region for hardware and data storage, for a statewide total of $100,000. These costs are higher than those associated with AVI technology because of the need for more sophisticated software and the larger data storage capacity required. The costs associated with technicians responsible for data processing and analysis were not estimated for the purposes of this analysis.

Accuracy

The accuracy of this technology will depend in part on the spacing of camera sites. At 10-mile spacing in rural areas (and five-mile spacing in urban areas) the technology should be quite accurate. In operation, this technology has demonstrated the capacity to accurately identify 65percent to 75percent of the vehicles passing a camera-equipped site, producing a larger data sample. The larger sample size makes it possible to improve overall accuracy by excluding vehicles that have stopped or deviated from the route. On well-traveled routes, this would be an advantage at 50-mile spacing as well as 10-mile spacing.

The following estimates assume 10-mile spacing on rural roadways and five-mile spacing on urban roadways included in the State Highway System Plan. As with AVI technology, this would almost triple the number of camera sites and the costs associated with equipping and maintaining them.

Capital cost of cameras. The number of reader sites on rural roadways would increase to 368 ($8,046,970) and an additional 39 sites on urban roadways ($1,088,519), for a total fixed capital cost of $9,135,489.

Maintenance and data download costs. These costs would increase with the number of additional reader sites installed. Annual costs on rural roadways of $132,480 and on urban roadways of $14,040 would result in a total annual cost of $146,520.

Central data processing costs. An increase in the number of reader sites should not impact the costs associated with central data processing.

Relative accuracy. The video imaging technology offers the potential of greater accuracy because of the higher volumes of vehicles it can capture. This assumes a well-traveled route on which 65percent of total vehicles exceeds the number of transponder-equipped vehicles under the AVI technology.

System Enhancements

Video imaging technology could be automated to provide real time data to traffic management centers. If sites were wired for data transmission, eliminating the need for the manual download of data, site maintenance was estimated at eight hours per site per year.

Electronic downloads of this data would be conducted over phone lines, which was estimated at $100 per month per road segments for a dedicated line. A road segment would typically have between two and eight reader sites. At 50-mile spacing on rural roadways, the costs associated with automation were estimated at $107,040 (basic cost level). At 10-mile spacing on rural roadways, this cost would increase to $161,520; and would cost an additional $20,160 to similarly equip readers on urban roadways. The total cost associated with automating the downloading and transmission of video imaging data under the "accuracy" scenario is $182,680.

GPS Floating Vehicle Technology

General Description

The floating vehicle method of determining traffic flow is a well-established practice. According to this method, a "floating average" speed is calculated by driving a vehicle in the flow of traffic and clocking the time it takes to travel between pre-determined points. Equipping "floating vehicles" with GPS technology creates two significant advantages over manual methods. First, only a driver is required because all location positions and times are determined automatically. Second, the location of specific bottlenecks or speed restrictions can be identified because the technology is able to determine the speed of the vehicle at every location along the route, as well as at the beginning and ending points.

There are no privacy issues with this method because it does not involve monitoring the speed of private vehicles.

Basic Costs

Capital cost of Vehicles. Any vehicle can be equipped to operate with GPS. For the purposes of floating vehicle speed studies, the cost of equipping a vehicle is estimated to be around $2,500. This includes approximately $1,000 in GPS receiving equipment along with a lap top computer on which to record data. The cost of the vehicle is estimated at $10,000, or half-time use of a vehicle that could be otherwise employed. One vehicle per region was assumed, for a total cost of $75,000.

Operating Costs. The operating costs depend on the time it takes to travel over a route, the number of times the route is checked, and the cost of the driver. For this analysis it was assumed that each segment to be monitored would be traversed eight times per year in each direction and the time required would include one-half hour per segment per direction in addition to travel time. The cost of conducting these runs was calculated assuming a rate of $30 per hour (including labor and overhead). The total annual cost for rural roadways would be $40,296. Implementing this technology on urban roadways would add $8,842.

A service fee for access to a differential correction receiver (necessary to increase accuracy of the satellite signal) was estimated at $750 per region, for a total cost of $4,500.

Central data processing costs. The cost of computers and software for processing of information was estimated at $6,500 per region, for a total cost of $39,000. The cost of personnel to analyze the data was not estimated.

Accuracy

The accuracy of this method is very good for the specific times monitoring runs are made. It also provides information on the location of speed changes, which is not available through other technologies. However, it does not provide constant monitoring, and in that sense is less accurate than the other options. Additional runs would add to the accuracy of the database, but there is no industry standard by which to gauge the number of runs needed to meaningfully increase accuracy.

The cost of additional runs can be calculated using a base figure of $10,000 for each additional round trip on all rural routes.

System Enhancements

The natural extension of this method is to equip probe vehicles with GPS technology, enabling more regular monitoring of roadways. This has been done with transit vehicles in some areas, but does not provide a true indication of speed since by nature these vehicles make frequent stops. Expansion to probe vehicles also would be quite expensive. While it would be theoretically possible to automate the downloading of data, providing real time information for traffic management purposes, the cost would be prohibitive.

Conclusions and Recommendations

This research demonstrates that it would be feasible to collect traffic speed data on a statewide basis using ITS technology. Based on AVI or Video Imaging technology, such a system could track vehicles between readers on major routes, collecting data on travel times on a twenty-four hour, seven-day per week basis. Alternatively, GPS floating vehicles could provide accurate information on speed profiles of major routes. Either or both technologies could be correlated with existing traffic count data, and would improve data available to WSDOT for planning and monitoring purposes.

While each of the three technologies evaluated are feasible, they also involve considerable initial expense and commitment to a new data gathering process. Recognizing this, we have developed the following observations and recommendations:

1. The most cost effective gains would be from using the GPS equipped floating vehicles to obtain better speed profiles on all major routes. A vehicle should be place in each region and a sampling plan developed so that truly representative data is obtained. For roads on which more accuracy is required additional runs can be made.
2. The AVI and video imaging systems are not significantly different in cost. The video imaging reader has the advantage that is does not require transponders on vehicles, which could lead to administrative burdens. Therefore, if there is a desire to implement point-to-point speed monitoring, the video imaging technology is preferred.
3. Compared to AVI, video imaging is still somewhat experimental. If this technology is implemented it would be best to chose one or two key routes and begin the implementation process as a demonstration project.
4. Regarding accuracy of AVI and video imaging, the ten-mile maximum reader spacing is strongly preferred over the maximum fifty-mile spacing. If either of these technologies is used it would be useful to study the results of alternative spacing by installing at the closer spacing and then comparing sampled data to determine the impact of removing intermediate readers.
5. In the longer term, linking data via phone lines may allow real time monitoring of speeds. Even if real time monitoring is not initially a consideration, use of phone lines to eliminate manual downloading of data will likely be cost effective in most situations.

6. WSDOT should continue to monitor emerging technologies for collecting and measuring traffic and speed data. For instance, at present the option of speed monitoring using cellular technology was dropped from the study because the required infrastructure does not yet exist in rural areas. However, if the required equipment were installed for other reasons it might well turn out to be cost effective to purchase the information for traffic monitoring purposes. Similar situations may develop with other technologies as well.

Table 1 – Cross-Cascades Corridor Analysis Project – ITS Speed and Data Options

	AVI	VIDEO IMAGING	GPS floating vehicle
Description of Technology	• Detectors located along route pick up signals from transponders located in passing vehicles • Determines speed by comparing times at which vehicle passes consecutive detectors	• Infrared cameras read license plates of passing vehicles • Privacy protected via software that truncates and encrypts license plate numbers • Determines speed by comparing times at which vehicle passes cameras	• Vehicle driven in flow of traffic, clocking the time it takes to travel between predetermined points • Calculates "floating average" • Can identify locations of bottlenecks or slower speeds
Basic Costs Baseline costs associated with establishing a system on the statewide road network identified in the Highway System Plan. Assumes 50 mile spacing of detectors for minimum levels of accuracy (AVI and Video Imaging).	• **Costs: Detectors** ⇒ $2,416,000 • **Cost: Transponders** ⇒ $40 per vehicle cost; total cost = $800,000 for fleet ⇒ Battery replacement cost = $220,000 every 4 years • **Cost: Manual Download** ⇒ Includes download and maintenance ⇒ Estimated at $30 per hour, one hour per month per site ⇒ Annual Cost = $50,760 • **Cost: Data Processing** ⇒ Computers, data storage and software = $60,000	• **Cost: Cameras** ⇒ $3,130,807 • **Cost: Manual Download** ⇒ Include download and maintenance ⇒ Estimated at $30 per hour, one hour per month per site ⇒ Annual Cost = $50,760 • **Cost: Data Processing** ⇒ Computers, data storage and software = $120,000	• **Cost: Equip Vehicle** ⇒ Per vehicle cost = $2500 ⇒ Assume one vehicle per region at $10,000 ⇒ Total Cost = $75,000 • **Cost: Vehicle Operation** ⇒ Assume 4 roundtrip runs per year for baseline accuracy ⇒ Annual Cost = $40,296 rural plus $8,842 for urban routes • **Cost: Satellite Signal** ⇒ Access differential correction receiver to increase accuracy of satellite signal = $4,500 • **Cost: Data Processing** ⇒ Estimated at $6,500 per region (hardware, software) ⇒ Total Cost = $39,000

Table 1 – Cross-Cascades Corridor Analysis Project – ITS Speed and Data Options (continued)

	AVI	VIDEO IMAGING	GPS floating vehicle
Accuracy Option Costs associated with closer spacing of readers for AVI & Video Imaging (10 mile spacing on rural roadways; 5 mile spacing on urban roadways) and number of runs for GPS	• **Cost: Detectors** ⇒ Additional reader sites, including installation on urban freeways ⇒ Total Cost = $7,440,000 • **Cost: Transponders** ⇒ Closer spacing of readers allows for a reduction in number of equipped vehicles on rural routes, which would be reallocated to cover urban routes • **Cost: Manual Download** ⇒ Increases with number of additional reader sites ⇒ Total Cost = $146,520	• **Cost: Cameras** ⇒ Additional reader sites, including installation on urban freeways ⇒ Total Cost = $9,135,489 • **Cost: Manual Download** ⇒ Increases with number of additional reader sites ⇒ Total Cost = $146,520	• **Cost: Vehicle Operation** ⇒ Increase accuracy with additional runs by GPS equipped floating vehicle ⇒ Additional round trip run on all rural routes = $10,000 ⇒ Fixed costs remain the same
System Enhancements Costs associated with providing real time data for the purposes of traffic management via phone lines	• **Cost: Automate Download** ⇒ Basic Cost Level = $ 90,120 ⇒ Accuracy Level = $132,840	• **Cost: Automate Download** ⇒ Basic Cost Level = $107,040 ⇒ Accuracy Level = $182,680	

Table 2 – Cross-Cascades Corridor Analysis Project – ITS Speed and Data Options Cost Summary

	AVI	VIDEO IMAGING	GPS floating vehicle
Cost Summary – Base System			
Fixed Costs	**$3,276,000**	**$3,250,807**	**$ 118,500**
Annual Operating Costs	**$ 50,760**	**$ 50,760**	**$ 49,138**
Other Costs (AVI battery replacement costs each 4 yrs.)	**$220,000**		
Ten Year Costs – Base System	**$4,223,600**	**$3,758,407**	**$609,880**
Increased costs for Accuracy Option			
Fixed Costs	**$5,044,000**	**$5,884,682**	**$0**
Annual Operating Costs (including electronic downloads)	**$82,080**	**$131,920**	**$49,138** (To double the number of base runs)
Cost Summary with Accuracy Option			
Fixed Costs	**$8,320,000**	**$9,135,489**	**$118,500**
Annual Operating Costs (including electronic downloads)	**$132,840**	**$182,680**	**$98,276**
Other Costs (AVI battery replacement costs each 4 yrs.)	**$220,000**		
Ten Year Costs with Accuracy Option	**$10,088,400**	**$10,962,289**	**$1,101,260**